Biting off more than we can chew? The current and future role of digital techniques in landscape archaeology

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5.1 Biting off more than we can chew? The current and future role of digital techniques in landscape archaeology

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ABSTRACT

In this paper, a broad overview is given of the recent development of digital techniques in landscape archaeology, and of the way in which these have effectively revolutionised the way in which we do landscape archaeology nowadays. Within this development, a number of fields can be identified where computer techniques are highly successful in producing better scientific results more efficiently. The main contribution of computer techniques to landscape archaeology is found in their application to the prediction and detection of archaeological remains, to exploratory data analysis and to the visualisation of research results. A number of examples are shown illustrating this. The paper also tries to address the more fundamental issue if the application of digital methods and techniques is actually helpful for developing new interpretations and theory. It is concluded that we are still facing some stiff challenges there that are closely related to the attitude of archaeology as a science to theory, but also to the difficulties of developing software tools that actually do what we need them to do.

KEY WORDS

digital techniques, landscape archaeology, archaeological theory

INTRODUCTION: THE DIGITAL REVOLUTION IN LANDSCAPE ARCHAEOLOGY

For those not so closely involved in the development of digital techniques within and outside (landscape) archaeology, it may not always be appreciated how quickly the digital world is changing. A short look at the amount and variety of software tools available for landscape archaeologists nowadays shows the speed at which these processes move. Freeware and open source packages like Python, Meshlab, LandSerf, Depthmap, gvSIG, Google Sketchup, Whitebox GAT, NetLogo, R and GeoDa may all be used for specific tasks that are of interest to (landscape) archaeologists. This list is far from exhaustive; and yet, almost all of these packages were either not available ten years ago, or have gone through significant modification and development. And more significantly: there will be very few landscape archaeologists who have used all of them, or even know what they can be used for. We are now far removed from the days when an archaeological 'computer specialist' could be relied on to be proficient in all the computer skills necessary for archaeological research.

Looking back however at how computers have slowly invaded the archaeological work process, one could be excused to say that this has not been a revolution at all, but a gradual integration of digital techniques in research, just like they have more and more influenced our daily lives without us really noticing. In practice, however, I think that for most archaeologists there has been a moment when certain digital techniques were really 'discovered' and fundamentally changed the way of doing research. And while the process of technological innovation may have been relatively slow, there can be no doubt that it has really revolutionised landscape archaeology. As an example, we can look at the way databases entered archaeology somewhere in the early 1970s: they were the domain of experts with arcane knowledge who needed days of effort to code field forms in a format that mainframe computers could read, and then again spend days trying to explore what went wrong. While the latter aspect certainly has not disappeared from daily research practice, the casual use that is now made of a package like MSAccess by archaeologists is far removed from those early days. And so it went with a number of techniques: at first slowly creeping into the research process, and now being fully accepted as indispensable to do landscape archaeological research. One of the developments that have truly revolutionised academic research over the past few years for example is the ongoing digitisation of paper sources, to the point where new and old academic journals are now mostly digital publications, and searching for information on virtually any subject has become much easier.

In this paper I want to take a closer look at what the digital revolution has achieved for landscape archaeology over the past five to ten years. In doing so, I will inevitably only discuss the broadest trends, and will gloss over certain aspects of computing that are of interest to landscape archaeologists. I will largely try to confine my conclusions to the areas where I feel that computer techniques have made the greatest contribution to landscape archaeology: prediction, detection and visualisation. And finally, I will try to address the issue if the application of digital techniques, and in particular quantitative modelling, is actually helpful for developing new interpretations and theory.

A REVOLUTION IN PREDICTION

One of the fields in landscape archaeology where computer techniques, in particular GIS and statistical software, have always been of primary importance is archaeological predictive modelling (see e.g. Judge & Sebastian 1988; Van Leusen & Kamermans 2005). It became firmly established in the time of what could be called the first wave of the digital revolution, where the availability of affordable software on personal computers suddenly opened up computing power to a much wider public. In its long association with digital techniques predictive modelling has witnessed significant changes as a consequence of developments in digital technology. A major factor has been the increasing availability of digital data sources. Only twenty years ago, there were almost no geographical and archaeological data available that could be used as input for predictive models, and almost everything that was needed to create predictive models had to be digitised by the archaeologists themselves. Nowadays, an enormous amount of digital data sources including a wealth of historical maps, digital elevation models and aerial photographs is available on-line, and increasingly it can be downloaded free of charge, or for highly reduced rates compared to the 1990s. Obviously, this makes it much easier to combine data sources and search for patterns and correlations between the archaeological data and the various environmental and historical sources available.

A second factor is the increasing availability of complex analysis methods in software. Geomorphometric indices for example, like the calculation of slope and curvature from digital elevation models, have always been part of GIS software, but it is only in the last few years that landscape archaeologists have become aware of the further analysis capabilities that are offered by packages like LandSerf (see also Hengl & Reuter 2009). These include the possibility to calculate scale-dependent, 'fuzzy' measures of landform (Fisher et al. 2004), like the degree of 'peakness' of the higher elevations in a landscape. And statistical analysis methods that are able to integrate expert judgment and 'hard' data have become available as well, like Bayesian statistical methods and Dempster-Shafer modelling (Ejstrud 2005; Van Leusen et al. 2009). These 'new' predictive modelling techniques are especially well suited to deal with the aspect of uncertainty of predictions, which could potentially provide a much better understanding of the value of the models made (Verhagen et al. 2010).

Powerful 3D 'solid modelling' software is now gradually becoming better affordable and easier to use, and will open up a whole new range of predictive modelling techniques based on both stratigraphic and geographic relationships (de Beer et al. 2011). An impressive example of what 3D modelling techniques can do for the prediction of archaeological resources is found in the North Sea Palaeolandscape Project (Gaffney et al. 2007). This project originally started as an experiment to see whether seismic profiles taken by oil companies in the North Sea could be used to map the palaeogeographical landscape features hidden under the sea floor. The seismic profiles in fact turned out to be very useful for this. However, the effort that was eventually undertaken to map much of the British North Sea was only possible through the use of high bandwidth computer networks and large data storage facilities.

But prediction is not all about formal statistical techniques and using big computers. Before going into the field for any type of fieldwork, no landscape archaeologist today will miss the opportunity to consult the available digital map resources. Of these, LiDAR-based elevation models are currently the most valued. But we have to realise that only ten years ago these were hardly available. In fact, the quality of LiDAR images has dramatically improved over the last few years as well. We can now get LiDAR data with a horizontal resolution of less than 1m, allowing us to detect microtopographical features that are com-

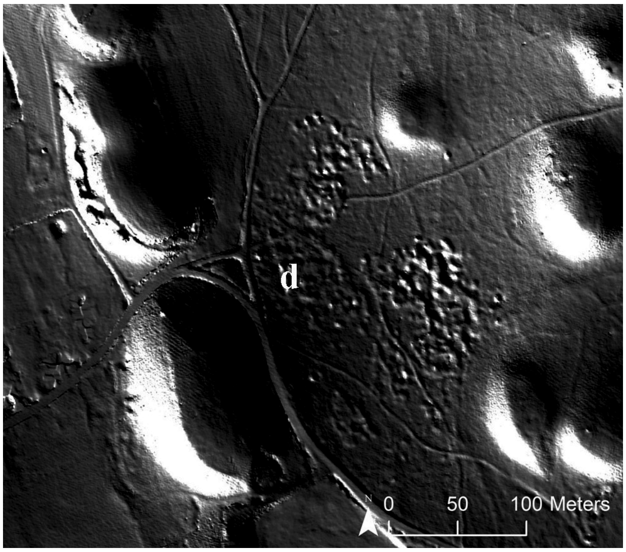


Figure 1. Example of the use of LiDAR images for the detection of archaeological features. Taken from: Opitz et al. (this volume).

pletely invisible from the ground and from aerial photographs (see fig. 1). Especially in forested areas, the contribution of LiDAR to the detection of archaeological features can be enormous (see e.g. Devereux et al. 2005; Doneus et al. 2008). Furthermore, image filtering techniques are still developing, and will hopefully lead to an increased application in areas where LiDAR is usually less successful, like ploughed fields. In an increased appreciation for remote sensing, in the 1990s and early 2000s, satellite images were considered to be perhaps useful for the detection of large archaeological features in arid countries, but not a true match for good aerial photographs (see a.o. Scollar et al. 1990; Fowler 2002). Because of the increased resolution of the available images, and the capture of multispectral images from airplanes, this has clearly changed (see e.g. Winterbottom & Dawson, 2005; Aqdus et al. 2007). With these multispectral and hyperspectral airborne images, we can now look at the landscape at the level of detail that is needed for archaeological prospection, and at the same time get all the added value of using image interpretation techniques, like band and image combination and (semi-)automated classification. And obviously LiDAR images and geophysical measurements can be combined successfully with multispectral images as well (e.g. Kvamme 2008).

A REVOLUTION IN FIELDWORK

In (geo-)archaeological fieldwork, the influence of digital technology is now more and more visible as well. Until the late 1990s, there were no practical systems for setting up wireless communication, and the available equipment was fragile and lacked easy-to-use software applications for use in the field. This has now completely changed, largely because the availability of affordable weather-resistant equipment has increased enormously. Especially in commercial archaeology, the use of field computers has by now become standard procedure, as it not only increases the speed at which measurements are taken and finds and features are recorded, but also diminishes the amount of error in registration, as it is possible to compare the results of recording with the situation in the field at virtually the same moment (Wagtendonk et al. 2009).

The accuracy of GPS measurements used to be an obstacle as well to the use of mobile field computing in archaeology; but the sub-metre precision that is in most cases required has now become affordable as well. And there will be more in the future: miniature helicopters equipped with GPS and stabilising platforms can now be bought at competitive prices and used to take photographs and make photogrammetric measurements of the earth's surface at a high level of detail (Eisenbeiss 2009).

One of the fieldwork activities that has always been highly dependent on computing techniques is geophysical prospection. In this field, the developments sketched on mobile computing have also increased its applicability. Especially the availability of high-precision GPS measurements has now made it possible to take geophysical measurements much quicker than before. It is now common practice to see archaeologists doing geophysical measurements with what basically looks like a high-tech lawnmower, or on a quad bike equipped with a GPS antenna. The level of detail at which these measurements are taken is increasing as well, although there still is a considerable amount of difference in the resolutions and speeds that can be obtained with the various methods available. Resistivity measurements for example always need physical contact of the probes with the earth's surface, which severely reduces the speed of measurement. Low-resolution methods using electromagnetic and self-potential techniques however can easily cover up to 5 hectares per day. Furthermore, signal detection and filtering methods have improved to the point where geophysics (and especially ground-penetrating radar) are now close to being able to detect individual features and larger artefacts, and can also be applied in soil types that until recently were not considered to be very well suited, like clay and peat.

Geophysical measurements are now routinely combined with other GIS-based and remote sensing data to aid interpretation. Furthermore, the increased processing power of computers, coupled to 3D processing software allows us to create 3D images of the subsoil from GPR measurements at a level of detail that was unthinkable 10 years ago. However, in spite of the use of clever image enhancement techniques, the delineation of subsoil features and their interpretation still seems to require a lot of expert judgment. One challenge for the future in geophysics would therefore be to investigate whether automated classification tools can be used to the same effect as in (airborne) remote sensing.

A REVOLUTION IN VISUALISATION

Landscape archaeologists are all familiar with the powerful mapping capabilities of GIS and there is an increasing awareness that visualisation of complex numerical data sets is becoming easier through the availability of powerful data mining software like Weka. However, 3D modelling is probably the field where developments are processing at the highest speed when it comes to more powerful ways of visualising research results. 3D modelling of especially ancient buildings and artefacts has been around for almost as long as GIS has been in place (see e.g. Reilly 1990; Forte & Siliotti 1997; Barceló et al. 2000). Up to now it has failed to make a real breakthrough to landscape archaeology. Partly this has been because of the complexity of creating 3D reconstructions, and the difficulty of using 3D reconstruction software in combination with GIS and/or solid modelling packages. It is however a commonly used and appreciated technique in urban archaeology and architecture. In recent years this field has experienced a massive growth in application and it is now becoming more and more accessible to users that are not skilled 3D modellers. The major reason for this has been the development of free and relatively easy to use software to make architectural reconstructions. Google Sketchup is currently the most widely used package to quickly create 3D models, that may not be up to the standards of real architects, but nevertheless can do a decent job in visualising the main features of buildings. And even game development software can be used to this effect, as is shown by the reconstruction of the Maya city of Chunchucmil by David Hixson using the Unreal Engine software (see en.wikipedia.org/wiki/File:Chunchucmil-reconstruction-2.jpg).

A relatively new development is the way in which photographs can now be combined into 3D images. The technique is quite simple, as it only needs overlapping photos. The information on focal distances contained in digital photographs is then used to compare overlapping photos and decide how they should fit together. This information can be used further to create 3D models from the pictures through photogrammetric techniques. This development will undoubtedly become very important in the near future, too, as it is a highly affordable alternative to traditional photogrammetry that can be used in all kinds of settings, including excavation pits. We can therefore expect an increasing synergy between the approaches used in architectural reconstruction, landform modelling and subsurface modelling, as they all can strengthen each other.

A REVOLUTION IN THEORY?

There is no doubt that powerful image capturing, manipulation and visualisation techniques will continue to attract the attention of landscape archaeologists in the near future. And in fact, we need time and experience with these new techniques to fully judge their applicability to the questions of prediction, detection, analysis and visualisation. But the question is: do all these developments really help us in interpreting the landscape and the archaeological record, and thus lead to new insights? Obviously, the detection of new, unsuspected features through, e.g. geophysics or LiDAR can lead to new insights, and a number of new descriptors of the landscape can easily be obtained from especially digital terrain models, including the now almost common calculations of viewsheds and cost surfaces in GIS.

One of the most interesting lines of research in landscape archaeological GIS in this respect has been the development of spatial descriptions of visibility of the landscape, in particular the work done by Llobera (2001, 2003, 2007). The use of viewshed techniques has now become standard issue in many GIS-based studies (see fig. 2), but it has also shown us how complex it is to use visibility as a measure of perception of the landscape. First of all, it is only one of the senses we use, be it probably the most important one. Modelling soundscapes (Mlekuž 2004) has not really caught on in landscape archaeology. The lack of reliable data on palaeo-vegetation is also an important issue to take into account here, especially since a human takes up a very small portion of space; views can be blocked very easily by a strategically placed obstacle, a fact that has been used to effect for many military and political purposes. Nevertheless, the analysis of the visual characteristics of the space that people lived in is often thought to contribute to a better understanding of how the landscape is structured from a human point of view. The use of the well-known Higuchi visibility ranges (see e.g. Wheatley & Gillings 2000) has therefore become quite popular in archaeological GIS-studies. And as there are very few researchers interested in both phenomenology and quantitative modelling, perhaps it would be good to look at a combination of both approaches, especially since virtual reality has now also become a major business in computing in and outside archaeology.

What is true for viewshed analysis probably becomes even more serious when we are looking at

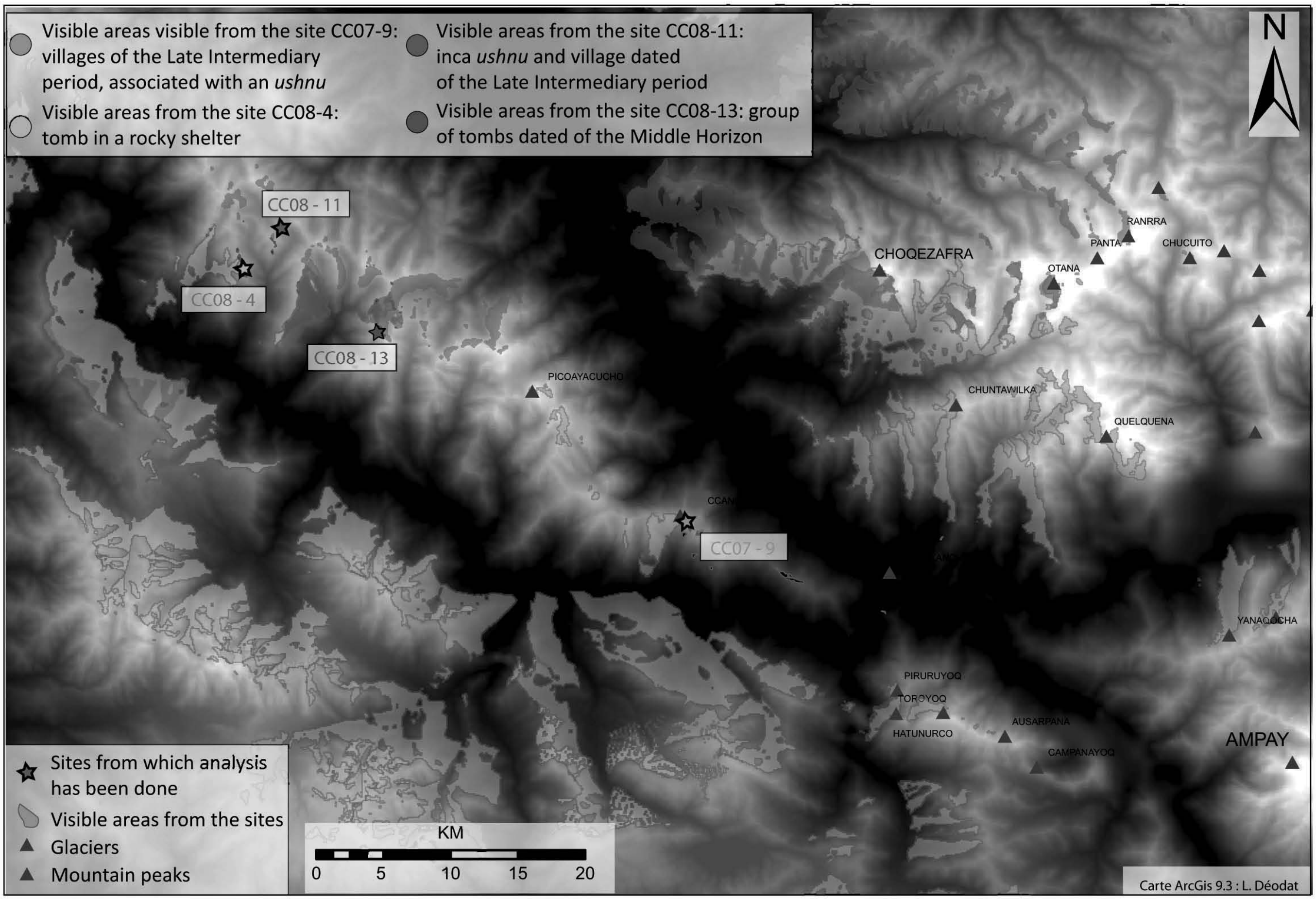


Figure 2. Example of viewshed analysis to map areas visible from archaeological sites. Taken from: Déodat and LeCocq (this volume). *See also 5.2 Figure 8 in the full colour section in this book*

modelling of prehistoric travel routes (see fig. 3). While it has in fact been one of the earliest archaeological uses of GIS to model terrain accessibility through cost surfaces (Gaffney & Stančič 1991), and finding the least cost paths to try to find out where people might actually have travelled, it is a field of research that has been almost completely neglected outside the community of archaeologists working with GIS, as is for example demonstrated in the papers in Snead et al. (2009). We know that there is much more to path finding than just a straightforward least cost path calculation, but no one seems to know what factors are actually influencing travel patterns. Furthermore, a whole field of research in space syntax (Hillier & Hanson 1984) and network analysis studies (Lock & Pouncett 2007) has mostly bypassed landscape archaeology and would need to be integrated with standard GIS analyses, and probably also with agent-based modelling, in order to make more progress in this respect.

New modelling techniques also try to capture the dynamics of complex socio-natural systems. As with all the other techniques shown, the development in this realm has gone fast over the past ten years. Tools that are currently available, for example for agent-based modelling, are very powerful and can easily be used with spatial data sets. Partial success can be observed, especially in cases where we can try to link human activities to natural processes like erosion. A much more difficult and controversial issue however is found when we consider the effects of the environment on human behaviour itself.

The debate on the value of dynamic simulation models however is far from new: in the 1970s a number of computer-based studies appeared (Doran 1970; Hodder 1977; Sabloff 1981) that claimed to model socio-natural systems into some detail, and these raised a wave of criticism. This is partly because all things quantitative fell out of grace with a large part of the archaeological community in the late 1980s with the rise of post-processual archaeology; but perhaps also because we do not really know whether these models offer realistic descriptions of how socio-natural processes operated in the past. There is an uneasy marriage between modern, post-processual and holistic archaeology and quantified modelling. On the one hand we have our (sometimes vague) ideas on how people lived and behaved within their cultural background, and how this related to their socio-cultural and natural surroundings. On the other hand we have our limited data sets of the environmental settings in prehistory, and in many cases an even more limited data set about the socio-cultural settings. Getting from relatively simple land use models based on relatively simple theories about subsistence economy to conclusions about the identity of prehistoric people may then seem a bit of a tall order, regardless whether we use quantitative modelling or not. However, I want to argue that this kind of modelling can certainly be used to effect, provided we do not use it as the ultimate means to reconstruct the past.

In other disciplines quantitative modelling is primarily seen as one of the potential tools to develop theories and interpretation, whereas archaeologists are usually much more concerned with the formulation of theory from logical argument. The scientific research process can in essence be seen as a slow movement along the lines shown in figure 4, sometimes going back and forth between the different stag-

Figure 3. Example of least cost path calculations using different specifications of movement costs, in a study area in Cappadocia, Turkey. Adapted from Verhagen & Polla (2010). *See also full colour section in this book*

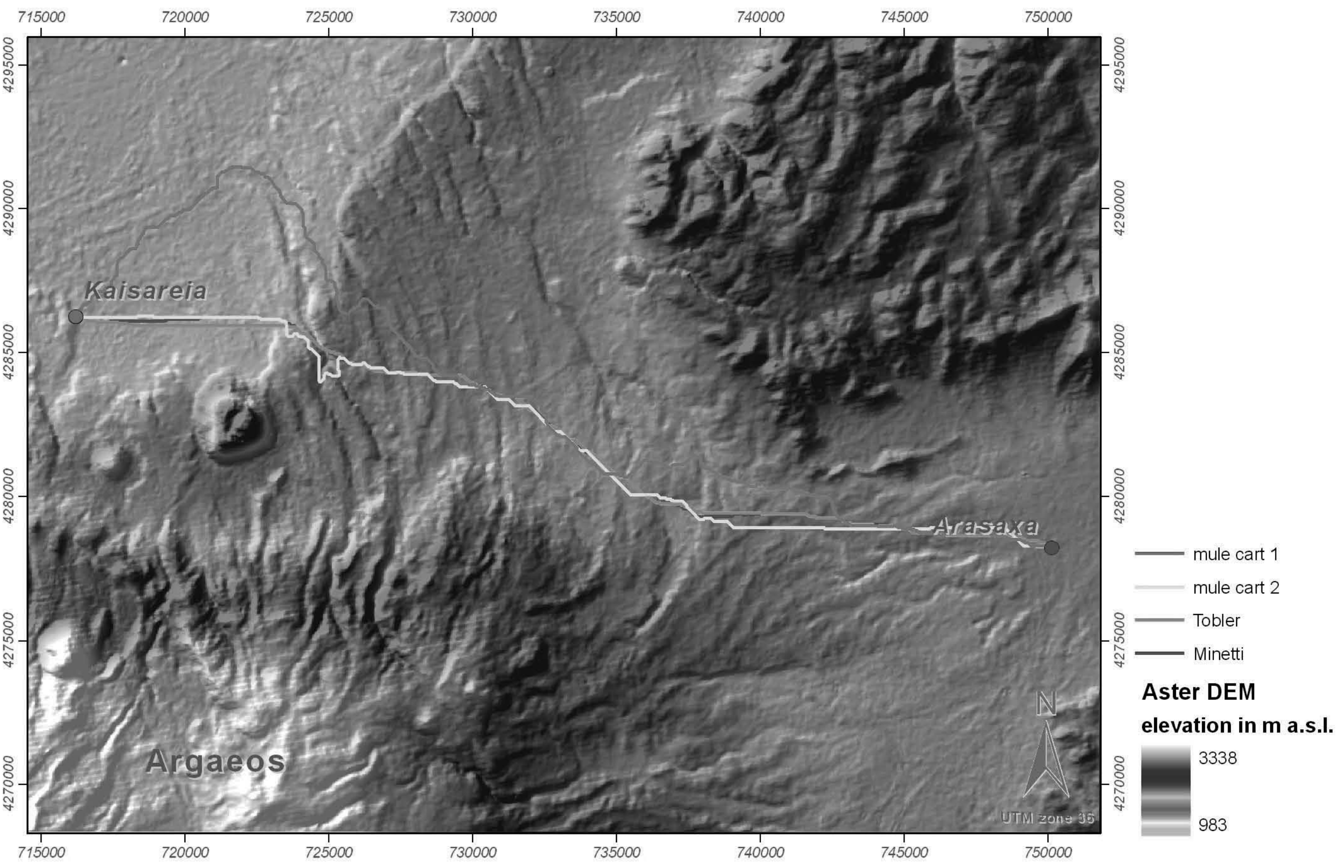
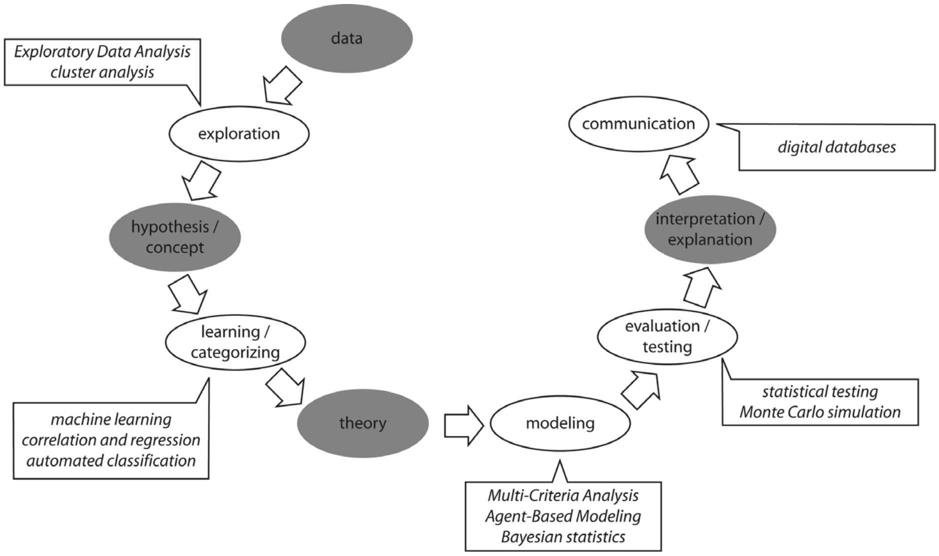


Figure 4. The position of modelling in the scientific research process. Quantitative methods and models can play a role in almost any stage of scientific research, but are best applied in the stages where theory is developed and made suitable for testing. The separation between hypothesis and theory however may not always be as clear as suggested. Adapted from O'Sullivan & Gahegan (2007).



es of theory formation and interpretation. In this particular scheme, the role of statistics is deliberately included to show what can be done with formal, computer-based methods, much more than is normally understood by archaeologists. However, using these techniques to effect takes a lot of effort since many of them are quite complex and need training to be properly executed and interpreted.

Most important in the scheme however is the position of modelling: it is situated after the formulation of theory. Modelling is a way of making a theory explicit and to open it up to testing. The true power of modelling techniques nowadays is that they allow us to quickly generate a number of scenarios and compare these to actual empirical data. Obviously, this also means that the role of modelling is limited to cases where we can specify scenarios quantitatively, and where we at least have the potential to test the models with data. If this is not the case quantitative models will be no better than speculation.

The need for quantitative modelling was eloquently phrased by Joshua Epstein (2008), one of the pioneers of agent-based modelling:

> The choice, then, is not whether to build models; it's whether to build *explicit* ones. In *explicit* models, assumptions are laid out in detail, so we can study exactly what they entail. On these assumptions, *this* sort of thing happens. When you alter the assumptions *that* is what happens. By writing explicit models, you let others replicate your results.
> (...)
> It is important to note that (...) models do *not* obviate the need for judgment. However, by revealing tradeoffs, uncertainties, and sensitivities, models can *discipline the dialogue* about options and make unavoidable judgments more considered (...).
> (...)
> Models can surprise us, make us curious, and lead to new questions (...).

He basically sees an important role for models as exploratory tools to judge the value of theories and concepts, and makes a plea for looking at these models as heuristic tools. However, this way of thinking about modelling has not made a real breakthrough in landscape archaeological research yet. The best-known example of this approach in landscape archaeology is probably the application of agent-based modelling techniques by Kohler et al. (2005) to simulate and better understand the population dynamics of the American south-west. In their case however, they had excellent data at their disposal to test the simulated population development.

So it seems that landscape archaeology is caught somewhere between the shining perspective of using quantitative models as exploratory, heuristic devices that can be used for a number of different research questions, and the technical and theoretical limitations of what we are trying to do with them.

A REVOLUTION IN ARCHAEOLOGICAL COMPUTING?

We also have to be aware that we are dealing with issues that are not only complex from a theoretical point of view, but from a computing point of view as well. There is an enormous amount of software tools available, but as a general rule, they will not work together seamlessly. In practice, an experienced 'computer archaeologist' will always have more than one option at hand to do the required task. But this comes at the price of having to transfer data between different packages, and to be able to judge what all these packages can do for you. The lack of good data standards both inside and outside archaeology is something that we have to live and deal with as best as we can.

More serious is the fact that the archaeological community has very few people who can do a decent job in programming. This is really something that should be at the top of our priority list if archaeologists do not want to be stuck with tools that were originally designed for completely different questions. The least cost path issue is an example of this: it has only dawned on archaeologists fairly recently that the standard tools for calculating these paths can produce different results, depending on the software package chosen (Herzog & Posluschny 2008). A tool that allows us to use all different techniques available and compare these still has to be released.

It seems that many computing solutions developed by archaeologists have been made on an ad hoc basis, and lack a firm integration in existing software platforms. Some quite useful software tools are therefore no longer available, like the agent-based modelling tools for GRASS made by Lake (2000). This is a real problem, since developing software is quite expensive, and maintaining it will always be cheaper than having to reinvent the wheel, even when in most cases it will mean redesigning the software every 5 to 10 years. We therefore need to prepare ourselves for a revolution in archaeological computing. Ignoring how to make software is not going to get us anywhere, and our best bet currently is to use the power of open source software development. While there is still a lot to be improved with regard to open source software, especially where it concerns user friendliness, it is the only way in which archaeologists can actively participate in the way in which software develops. Open source software plays a key role in making innovative methods and tools available to the scientific community. A main reason why a number of useful tools are not more widespread is because of software licensing costs and the fact that closed source software cannot be modified, enhanced and then freely shared by its users, thereby severely limiting its usefulness for science. A first step in this direction has been the establishment of the Open Archaeology website, sponsored by Oxford Archaeology (www.openarchaeology.net). However, this approach will only work if archaeologists start to contribute actively to its maintenance and provide ideas for further development.

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